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# Object-Based Attention: A Within-Object Benefit and Sensory Enhancement in Discrimination Tasks

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Object-based attention (OBA) will result if a target appearing at an invalid location on the same object is detected more quickly than a target at an equidistant location on a different object. The current study first asked whether the object effect obtained in the discrimination task was a result of within-object benefit or between-object cost. To answer this, Experiment 1 added an object-absent baseline to the cuing paradigm of Egly, Driver, and Rafal (1994). Perceptual load was manipulated, in which the low-load color and the high-load color/shape conjunction discrimination tasks were adopted. Results favored the within-object benefit hypothesis. The current study further asked whether this within-object benefit was a result of sensory enhancement or attentional prioritization. Experiment 2 adopted the data-limited accuracy measure in order to examine the strength of object representation. In the low-load condition, attention was distributed in a similar manner on the attended and unattended objects. In the high-load condition, attention was allocated within the attended object, favoring the sensory enhancement. The implications of current results are discussed.

**Keywords:** *attentional prioritization, baseline, benefit, cost, sensory enhancement*

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Object-based attention (OBA) theories (e.g., Duncan, 1984; Egly et al., 1994; Ho & Yeh, 2009; for a review, see Scholl, 2001; Vecera & Behrmann, 2001) have shown that the units of selection can be discrete objects, in addition to spatial locations. One classic example of OBA is the work by Egly et al. (1994) which used a cuing paradigm to demonstrate the existence of OBA. The display contained two outline rectangles; prior to the target onset, a cue that predicted the target location with greater than chance probability flashed at one end of one rectangle. On invalid cue trials, responses were faster for targets appearing at the other end of the cued rectangle than at the uncued rectangle, with an equal cue-target distance between the two (an object effect). There are at least two possibilities accounting for the object effect obtained in Egly et al.'s cuing paradigm (1994): the between-object cost and the within-object benefit hypotheses.

## Between-Object Cost Hypothesis

The object effect may be due to a cost related to the shift of attention from the cued object to the uncued one (i.e., the between-object cost hypothesis). Lamy and Egeth (2002) employed various tasks (detection, discrimination and flanker tasks) and only found the object effect when attentional shift was required. That is, they obtained the object effect only when attention was needed to shift from the exogenously cued object to the uncued object or for a shift between two asynchronously-onset targets in different objects. Extending Lamy and Egeth's work (2002), Brown and Denney (2007) used one- and two-rectangle displays to examine the object effect related to disengaging and engaging attention within, between, into, and out of objects. They found that the RT costs for location-to-object shifts were less than those for object-to-location or object-to-object shifts, but that the costs for the latter two conditions were comparable. They suggested that the object effect is primarily associated with disengaging operations from the attended object.

## Within-Object Benefit Hypothesis

In addition to the between-object cost, object effect could also be a benefit related to attentional processing within the cued object (i.e., the within-object benefit hypothesis)[1]. The evidence supporting the within-object benefit hypothesis is primarily generated by studies supporting sensory enhancement and attentional prioritization accounts.

### Sensory Enhancement and attentional Prioritization Accounts

Many studies have suggested that the deployment of attentional resources regarding a cued object improves the strength of that object representation (i.e., the sensory enhancement account; e.g., Chen & Cave, 2008; Ho & Atchley, 2009; Martínez et al., 2006; Richard, Lee, & Vecera, 2008). Thus, the cued objects to which attentional resources are allocated have greater spatial resolution than those to which no or little attentional resources were allocated (Carrasco & Yeshurun, 2009).

On the other hand, there may not be sensory enhancement for locations within objects, but only a priority assignment to the unselected locations within the attended object (i.e., the attentional prioritization account; Shomstein & Yantis, 2002, 2004). When attention moves within regions of space, the presence of objects guides the attention to first search within the boundaries of those objects, and then the locations outside those boundaries, thus leading to faster RTs for the target in the cued object.

### RT vs. ACC Measures

The sensory enhancement account is usually considered a contrast to attentional prioritization account. One of the biggest differences between these two accounts regards the strength of object representations. The sensory enhancement account postulates that the enhanced object representation is critical for OBA; whereas the attentional prioritization account proposes that there is no sensory enhancement, only a prioritization process. The data-limited accuracy (ACC)-based measure (Ho & Atchley, 2009; Marino & Scholl, 2005; Norman & Bobrow, 1975; Prinzmetal, McCool, & Park, 2005; Santee & Egeth, 1982) has been viewed as an effective tool for measuring the strength of object representations. Because one of the differences between the sensory enhancement and attentional prioritization accounts lies in the strength of object representation, the adoption of the data-limited ACC-based measure is critical for distinguishing between these two accounts (Ho & Atchley, 2009). The data-limited condition is met by reducing the target exposure time (e.g., the target is masked after a brief target exposure time). In this case, the ACC data reflects the effectiveness of the processes which extract information from the stimuli. Because the responses are not accelerated in the data-limited condition (and therefore lead to no speed stress), later processes (e.g., response selection and execution) can be accomplished equally well across manipulated conditions. It has been argued that through the use of ACC-based measures can one distinguish the enhancement effects (Prinzmetal et al., 2005).

### The Role of Perceptual Load

The degree of perceptual load can affect the occurrence of OBA. More importantly, this relationship is better observed by using the data-limited ACC-based measure. Ho and Atchley (2009) manipulated the cue-target distance and the perceptual load of target (e.g., color feature vs. color/shape conjunction). Specifically, they compared the data-limited ACC-based measures and the typical RT-based measures to investigate load-modulated OBA. They reported that the data-limited ACC-based measures were more sensitive to load-modulated attentional selection over the objects (Lavie, 1995, 2005; Lavie, Hirst, de Fockert, & Viding, 2004). Specifically, RT-based measures across different perceptual load conditions showed similar OBA. On the other hand, ACC-based measures showed that attentional resources were modulated by the amount of perceptual load. Under conditions of low load, attention could extract more information from both the attended object and nearby locations, leading to greater ACCs on the attended object and the nearby locations. When the perceptual load increased, attention was highly localized but still favored the attended object, again causing greater ACCs on the attended object. These results were inconsistent with the attentional prioritization account. This account suggests that the representation of the attended object would not be enhanced; therefore, it would predict equivalent ACCs between the attended and unattended objects.

Since perceptual load can modulate attentional selection over objects, it is important to manipulate the degree of perceptual load, rather than adopting only one level of perceptual load. Adopting only one level of perceptual load (e.g., a very low load) may produce a result that erroneously rejects the sensory enhancement account (e.g., comparable accuracy rates between the attended and unattended objects). Thus, both high and low perceptual loads were used in the current study.

## Object-Absent Baseline

Recently, Ho and Atchley (2008) added an object-absent condition as a baseline to the Egly et al.'s cuing paradigm (1994) and reported a larger RT difference in shifting from the cued object to the uncued one, than in moving an identical distance in space, indicating a between-object cost. Removing the objects (i.e., the object-absent condition) eliminates any object-based benefits, providing a bias-free measure of the amount of time it takes to move attention between locations. If the objects induce a cost for shifting between them, then greater RTs would be expected in the different-object case versus the time to switch attention over that distance in space. In contrast, if the objects facilitate the processing of a target within the attended object, then smaller RTs would be found in the same-object case versus the time to shift attention over that distance in space.

Without the adequate baseline (e.g., an object-absent condition in Brown and Denney [2007] and Ho and Atchley [2008]), one may have difficulty distinguishing whether OBA is caused by a between-object cost or a within-object benefit (to be discussed later). For example, in Lamy and Egeth's (2002) study in which an attentional shift was required (Experiments 2 and 3), because of a lack of object-absent baseline, one can argue that the object effect derived from these experiments was not associated with a cost to shift attention between objects, but with a processing advantage for the target within the attended object.

## The Current Study

There were two questions asked in the current study. First, could the object effects obtained in the discrimination task be the result of a within-object benefit or a between-object cost? To answer this, Experiment 1 added an object-absent baseline to Egly et al.'s cuing paradigm (1994; e.g., Ho & Atchley, 2008). If the between-object cost hypothesis was supported, attention should take more time to move across objects, in comparison to the same distance in space without objects. Alternatively, if the within-object benefit hypothesis was supported, attention should take less time to move within object, in compareson to the same distance in space.

We adopted the discrimination task, because studies using behavioral measures (e.g., Brawn & Snowden, 2000; Vecera & Farah, 1994) and electrophysiological measures (e.g., Kasai, 2008) have shown that discrimination task relies on the high-level object representations (for more discussion, please refer to "Between-Object Costs or Within-Object Benefits in the RT-Based Cuing Tasks?" in General Discussion). Therefore, the within-object benefit may be more likely to occur by using discrimination task.

Second, is the within-object benefit attributed to the signal enhancement within the attended object (i.e., the sensory enhancement account) or to a prioritization process on the attended object (i.e., the attentional prioritization account)? To answer this question, Experiment 2 adopted the data-limited ACC measure to examine the strength of object representation (e.g., Ho & Atchley, 2009). Moreover, perceptual load was manipulated to investigate the possible changes in attentional allocation regarding the objects.

If the sensory enhancement account was supported, cue validity × perceptual load interaction was predicted since data-limited ACC-based measures were sensitive to load-modulated attentional selection on the objects (Ho & Atchley, 2009). That is, ACC differences between objects might be modulated by different levels of perceptual load. When load was low, relatively farther locations may be selected (e.g., Caparos & Linnel, 2009; Lavie, 1995; Müller, Mollenhauer, Rösler, & Kleinschmidt, 2005), which possibly reduces the attentional difference between the attended and unattended objects. When load was high, attention may be allocated locally, possibly increases the ACC difference between objects.

Alternatively, if the attentional prioritization account was supported, only the cue validity main effect was predicted. Specifically, the performances should be comparable when the invalidly-cued target was in the attended object and when it was in the unattended object.

## Experiment 1

The current experiment was designed to investigate whether the RT-based object effect obtained in the discrimination task is a result of within-object benefit hypothesis or between-object cost. An object-absent baseline was added to distinguish between these two hypotheses. Additionally, perceptual load was manipulated using low-load color discrimination and high-load color/shape conjunction discrimination. Although perceptual load has been shown not to affect RT-based object effects (Ho & Atchley, 2009), it was still manipulated here for two reasons. First, we can generalize the conclusion regarding cost and benefit to various levels of perceptual load, and rule out the possibility that cost or benefit only occur under some specific levels of perceptual load. Second, we can provide convergent evidence supporting the conclusion that perceptual load did not affect RT-based object effects (Ho & Atchley, 2009).

### Method

#### *Participants*

All participants in this study were undergraduates from Chung-Shan Medical University. Participants in each load task achieved over 90% accuracy. Each had normal or corrected-to-normal vision. There were 32 undergraduate students in low-load task and 32 in high-load task.

#### *Apparatus*

The stimuli were constructed with, and controlled by, E-prime software (Schneider, Eschman, & Zuccolotto, 2002), and were presented on a 17-inch calibrated View Sonic color monitor (at a refresh rate of 85 Hz) in a dimly lit chamber. The participant placed his/her head on a chin rest and viewed the stimuli binocularly at a distance of 50 cm. The apparatus was the same in Experiment 2.

***Design***

The current experiment consisted of two tasks: low- and high-load tasks. In the low perceptual load task, the task of the observer was to discriminate the color (blue vs. purple) of the target, regardless of its shape. In high perceptual load task, the task of the observer was to discriminate the conjunction of color and shape (blue circle and purple square vs. blue square and purple circle). Each experiment consisted of the object-present and object-absent conditions, and the order of the conditions was counterbalanced across participants. The only difference between these two conditions was that in the object-absent condition there were no objects in the display throughout the trials. In the object-present condition, the objects were two outlines of rectangles (color gray, each subtending $1.8^{\circ} \times 7.5^{\circ}$), with the distance $3.9^{\circ}$ between the two interior sides of the rectangles. The rectangles could orient either vertically or horizontally with equal probability. An L-shaped cue (color red, $1.8^{\circ} \times 1.8^{\circ}$) that was the bracket-shaped cue with the line on the interior side of rectangle (close to the central fixation) removed was adopted. The two lines of L-shaped cue pointed to two invalidly-cued targets, thereby not biasing attentional shift to either one in the object-absent and object-present conditions. There were two colors (blue or purple) × two shapes (circle or square), combinations of target with equal probability: blue circle, blue square, purple circle or purple square. The square was $0.9^{\circ} \times 0.9^{\circ}$ and the diameter of the circle was $0.9^{\circ}$.

There were 20 practice trials and 320 formal trials in each of the object-present and object-absent conditions. The target appeared at the cued location in 80% of trials (the valid condition). In the remaining 20% of invalid trials, the target could appear at either the uncued location occupied by the cued object (10%; the invalid-same condition, IS) or at an equidistant location on an uncued object (10%; the invalid- different condition, ID). Breaks were given every 20 trials. For the object-absent condition, there were no same or different object cases. In such condition, moving direction (either vertically or horizontally) was used to define invalidly-cued target. A vertical movement condition means that a target was on the top or bottom of a cue, requiring a vertical movement from this cue. A horizontal movement condition means that a target was on the left or the right side of a cue, requiring a horizontal movement from this cue. In the remaining 20% of invalid trials, the target could appear either left or right side to the cue (10%; horizontal movement) or at either top or bottom of the cue (10%; vertical movement).

The independent variables were object presence (present or absent), load type (low or high) and cue validity (valid, IS or ID in the object-present condition, and valid, horizontally or vertically in the object-absent condition).

***Procedure***

In the object-present condition in low- and high-load tasks, every trial began with a fixation point and two outlines of rectangles presented for 1000 ms (see Figure 1). Participants were instructed to fixate the central fixation point through each trial and were instructed that a target was most likely to appear in the cued location. Since the cue was equally probable to appear on one of the four locations, the best strategy for participants was to look at the fixation point to expect for the cue. An L-shaped cue was presented for 100 ms, followed by a 200-ms display consisting of a fixation cross and the double rectangles, and then the target. The target remained on until the observer response or for 2 seconds, which was recorded as an error. Sound feedback was given when the participant made an incorrect response. Participants pressed either "z" or "/" on a keyboard to respond to the two corresponding targets, counterbalanced across participants. In the object-absent condition in low- and high-load tasks, the procedure was similar to that in the object-present condition except that the objects were absent.

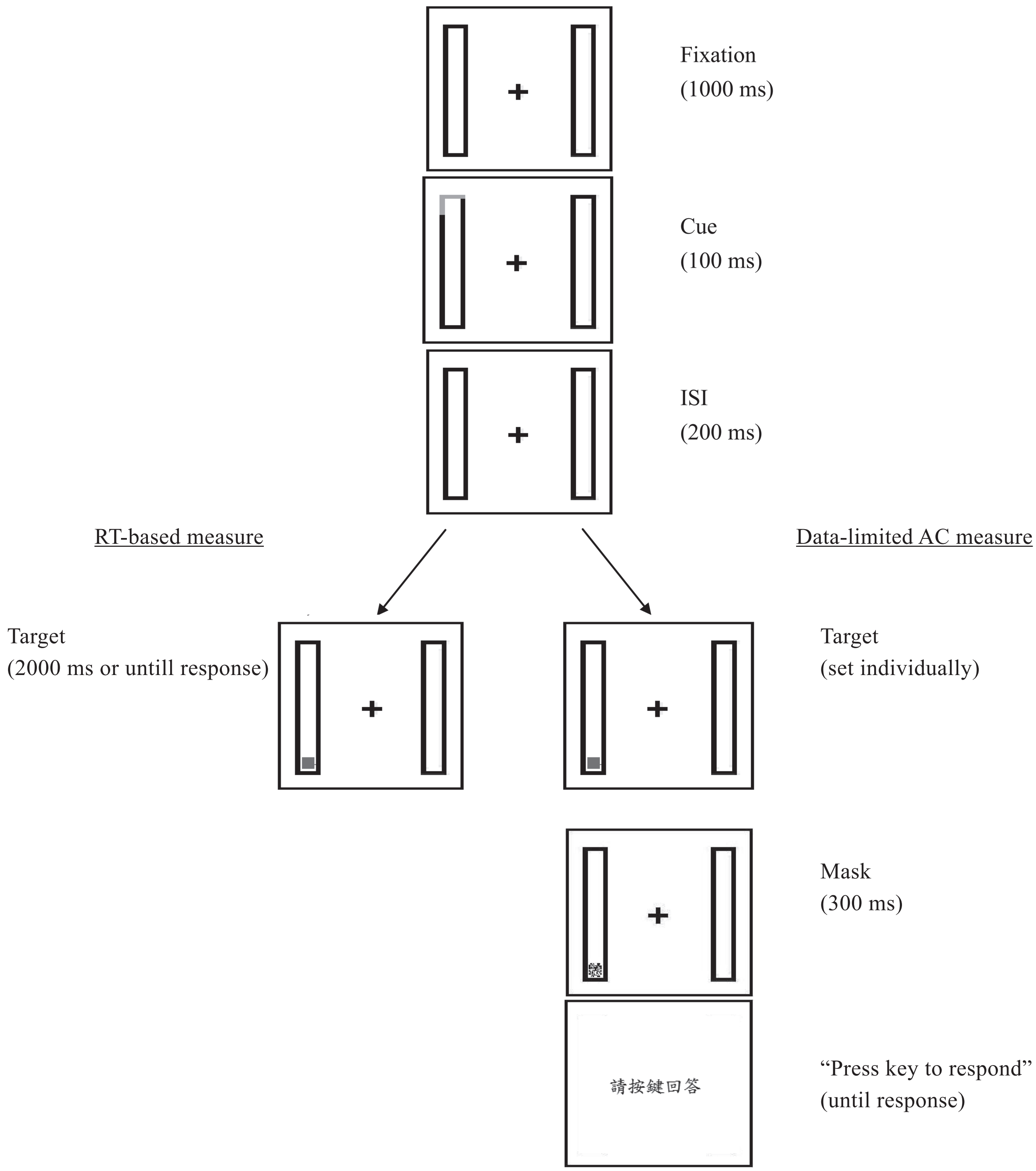



*Figure 1.* **Sample trial sequence for RT-based measure (Experiment 1; left column) and data-limited ACC measure (Experiment 2; right column). The primary difference between these two measures is the addition of the mask in the data-limited ACC measure. See text for details.**

## Results and Discussion

Data from Experiment 1 are presented in Figures 2 and 3. The correct rate was 96% in low-load task, and 94% in high-load task. Correct RTs faster than 200 ms and beyond three standard deviations from the grand mean RT were removed; this resulted in a 2.0 % removal rate in the low-load task and the high-load task.

First, to examine the typical object effect in the discrimination task when the objects were present, a two-way mixed analysis of variance (ANOVA) of load

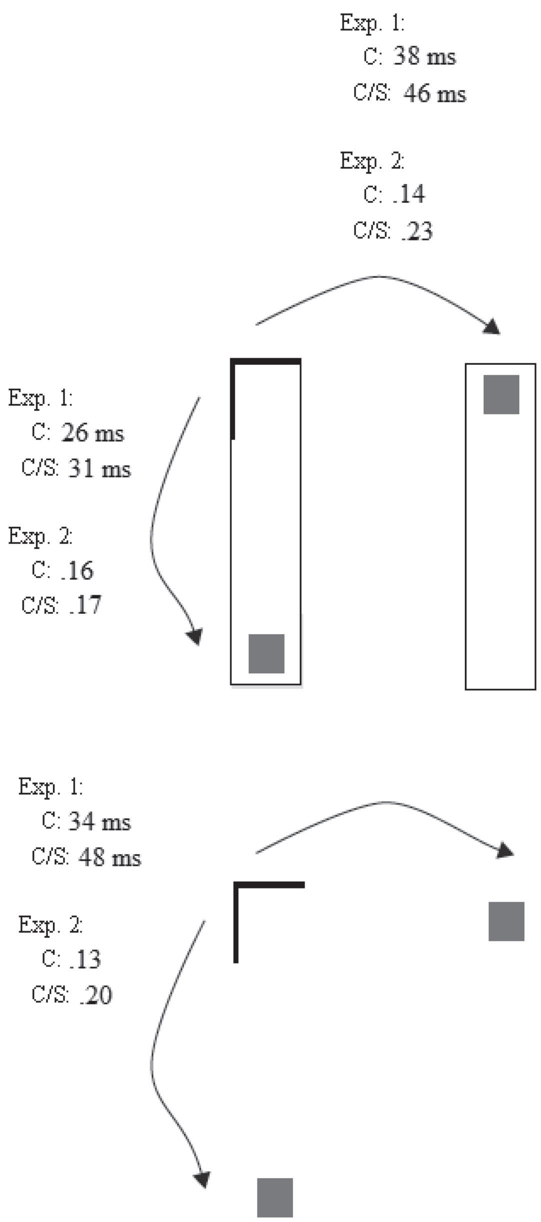
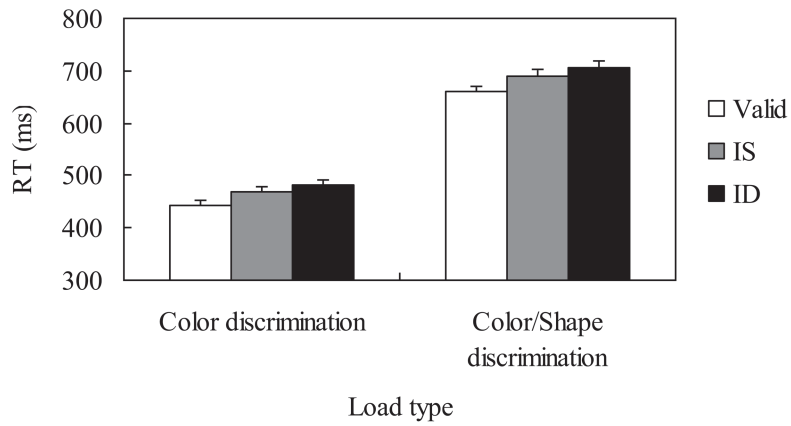



***Figure 2.*** **Summary of the RT and ACC differences in the object-present (top) versus object-absent conditions (bottom) in Experiments 1 and 2. C = Color, C/S = Color/Shape conjunction. The gray square represents the possible invalidly-cued target locations, given the cue in the top left corner. Note that the values in the object-absent condition (bottom) are the pooled values (see text for details).**

Object-present condition:




Object-absent condition:

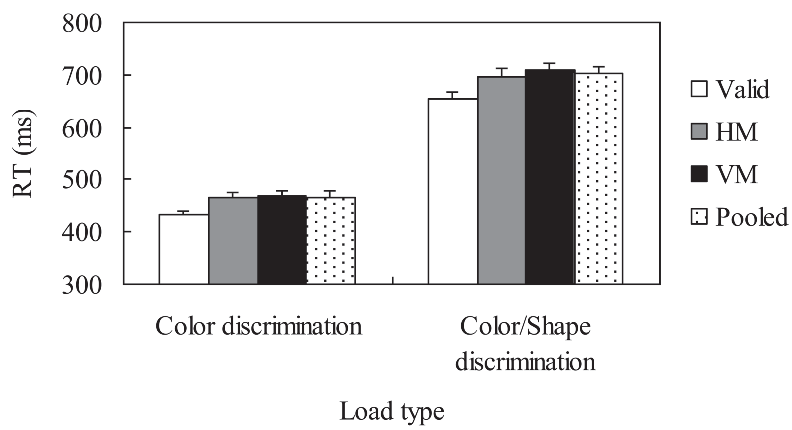



***Figure 3.*** **Mean RTs (in ms) across conditions in Experiment 1. Standard errors of mean are shown in the parenthesis. V = valid, IS = invalid-same, ID = invalid-different, HM = horizontal movement, VM = vertical movement, Pooled = pooled HM RT and VM RT.**

type (low or high) × cue validity (valid, IS or ID) on RT was conducted. The former was a between-subject variable and the latter was a within-subject variable. The interaction was not significant, $F(2,124) = 0.57$, $MSE = 424.4$, $p = .565$, $\eta_p^2 = .01$. Main effects of load type, $F(1,62) = 212.61$, $MSE = 10844.6$, $p < .0001$, $\eta_p^2 = .77$, and cue validity, $F(2,124) = 67.74$, $MSE = 424.4$, $p < .0001$, $\eta_p^2 = .52$, were significant. To further examine the main effect, we conducted post hoc comparisons in all experiments by using the Fisher's least significant difference (LSD) procedure. Longer RTs were obtained in high-load task (mean RT = 685 ms) than in low-load task (mean RT = 466 ms), revealing a successful load manipulation. To rule out the possible confounds from invalid RTs, the author compared the valid RTs between the high- (mean RT = 659 ms) and low-load (mean RT = 444 ms) tasks, and obtained a significant difference, $F(1,63) = 222.62$, $MSE = 3320.6$, $p < .0001$, $\eta_p^2 = .78$, again suggesting a successful load manipulation. RTs were shorter in the valid condition (mean RT = 552 ms) than in the IS condition (mean RT = 580 ms) and the ID condition (mean RT = 594 ms) (all *p*s < .0001). The RTs in the IS and ID conditions were significantly different ($p < .0001$), indicating the typical object effect in Egly et al.'s cuing paradigm (1994).

A two-way mixed ANOVA of load type × cue validity on ACC did not reveal any effects (all *p*s > .1), indicating comparable accuracy rates in all conditions.

Second, to examine the object-absent baseline condition, a two-way mixed ANOVA of load type (low or high) × moving direction (valid, horizontally or vertically) was conducted. There were significant main effects of load type, $F(1,62) = 208.08$, $MSE = 12247.3$, $p < .0001$, $\eta_p^2 = .77$, and moving direction, $F(2,124) = 67.61$, $MSE = 535.8$, $p < .0001$, $\eta_p^2 = .52$. No significant interaction was found, $F(2,124) = 2.35$, $MSE = 535.8$, p = .10, $\eta_p^2 = .04$. Longer RTs were found in the high-load task (mean RT = 686 ms) than in the low-load task (mean RT = 456 ms), $F(1, 62) = 216.00$, $MSE = 3864.2$, $p < .0001$, $\eta_p^2 = .78$, indicating a successful load manipulation. Valid RTs between the high- (mean RT = 654 ms) and low-load (mean RT = 433 ms) tasks were also significantly different, again supporting a successful load manipulation, $F(1,62) = 240.87$, $MSE = 3244.2$, p < .0001, $\eta_p^2 = .80$. The moving direction main effect showed the shortest RTs in the valid condition (mean RT = 544 ms) (all *p*s < .0001), and that there was no RT difference between the horizontal movement (mean RT = 581 ms) and the vertical movement (mean RT = 588 ms), $p > .1$, $\eta_p^2 = .05$. Since it took similar time to move horizontally and vertically in space, the RTs in these two conditions were pooled in the following analysis (hereafter, the pooled RT).

A two-way mixed ANOVA of load type × moving direction on ACC showed main effect of load ($p = .03$), revealing a higher ACC in low-load task (mean ACC = .97) than high-load task (mean ACC = .95). There were no other significant effects (all *p*s > .8). Together, the current ACC and the aforementioned RT results showed higher ACC in low-load task than in high-load task, and longer RT in high-load task than in low-load task. This negative correlation between RT and ACC indicated that there was no speed-accuracy tradeoff (positive correlation between RT and ACC).

Finally, the within-object benefit hypothesis was tested by comparing the time to shift within object (the IS RT: the valid RT with objects) with the time to shift between the same regions without objects (the pooled RT: the valid RT without objects). The between-object cost hypothesis was tested by comparing the time to shift between objects (the ID RT: the valid RT with objects) with the time to shift between the same regions without objects (pooled RT: valid RT without objects). These two hypotheses were tested in both low- and high-load tasks, respectively. In this planned comparison, the significance level of each comparison was compared to alpha = .05.

For the low-load task, the time to switch attention between objects (38 ms = ID RT 482 ms – valid RT 444 ms) was not significantly different from that switching attention between the same regions in space (34 ms = the pooled RT 467 ms – the valid RT 433 ms), $F(1,31) = 0.76$, $p = .391$, $\eta_p^2 = .024$. However, it took less time to shift attention within an object (26 ms = IS RT 470 ms – valid RT 444 ms) than to switch attention between the same regions in space (34 ms = the pooled RT 467 ms – the valid RT 433 ms), $F(1,31) = 4.71$, $p < .05$, $\eta_p^2 = .13$. This result favored the within-object benefit hypothesis.

For the high-load task, the time to switch attention between objects (46 ms = ID RT 705 ms – valid RT 659 ms) was not significantly different from the time switching attention between the same regions in space (48 ms = the pooled RT 702 ms – the valid RT 654 ms), $F(1,31) = 0.14$, $p = .706$, $\eta_p^2 = .005$. However, it took less time to switch attention within an object (31 ms = IS RT 690 ms – valid RT 659 ms) than to switch attention between the same regions in space (48 ms = the pooled RT 702 ms – the valid RT 654 ms), $F(1,31) = 8.88$, $p < .01$, $\eta_p^2 = .22$. This result also favored the within-object benefit hypothesis.

In both low- and high-load tasks, the time to switch attention between objects was not significantly different from that switching attention between the same regions in space, thus, a between-object cost can be rejected. The next experiment adopted the data-limited ACC measure to examine whether this within-object benefit was attributed to the sensory enhancement or the attentional prioritization account.

## Experiment 2

The present experiment was designed to examine whether the within-object benefit found in Experiment 1 attributed to the signal enhancement within the attended object (the sensory enhancement account) or a prioritization process on the attended object (the attentional prioritization account). The data-limited ACC measure was employed to examine the strength of object representation (e.g., Ho & Atchley, 2009). The perceptual load was manipulated as in Experiment 1, in which the low-load color discrimination was adopted in low-load task, and high-load color/shape conjunction discrimination was adopted in high-load task.

If the sensory enhancement account was supported, then the cue validity × perceptual load interaction was predicted (Ho & Atchley, 2009). Alternatively, if the attentional prioritization account was supported, only the cue validity main effect was predicted. Specifically, the data-limited ACC performances should be comparable when the invalidly-cued target was in the attended object and when it was in the unattended object.

### Method

#### *Participants*

All of the participants in this study were undergraduates from Chung-Shan Medical University. Each had normal or corrected-to-normal vision. There were 20 undergraduate students in low-load task and 20 in high-load task. Participants in these tasks achieved an accuracy rate between 70 % and 90 %.

#### *Design*

The design was similar to that in Experiment 1, except that only a data-limited method was adopted. In each of the object-absent and object-present conditions, participants completed 20 practice trials, 4 buffer trials and three blocks of 20 calibration trials, followed by 320 formal trials. The mask was $0.9^\circ \times 0.9^\circ$ and consisted of white random dots against the black background.

The independent variables in the object-present condition were load type (low perceptual load or high perceptual load) and cue validity (valid, IS or ID). The independent variables in the object-absent condition were load type (low perceptual load or high perceptual load) and moving direction (valid, horizontally or vertically).

#### *Procedure*

The target presentation duration in the practice trials was 100 ms in both low- and high-load tasks. The target presentation duration in the buffer trials was 40 ms in low-load task and 60 ms in high-load task.

In the calibration trials, variable target presentation duration was adaptively adjusted for each participant in order to maintain an accuracy rate of about 80%. The target presentation duration was adjusted every ten trials, producing six adjustment times in total in the calibration trials. The initial target presentation duration was 40 ms in low-load task and 60 ms in high-load task. Each adjustment was based on the performance in the previous ten trials. When the mean accuracy rate in the previous ten trials was above (or below) 80%, the target presentation duration was decreased (or increased) by a step duration of 2 ms[2]. The target presentation duration produced in the final adjustment of the calibration trials was used as the initial target presentation duration in the formal blocks. To prevent practice effects in the formal blocks that could increase the mean accuracy rate to over 80%, target presentation duration was further adjusted in the formal blocks. Therefore, in the current study, the target presentation duration in the formal blocks was adjusted every 20 trials with a step duration of 2 ms.

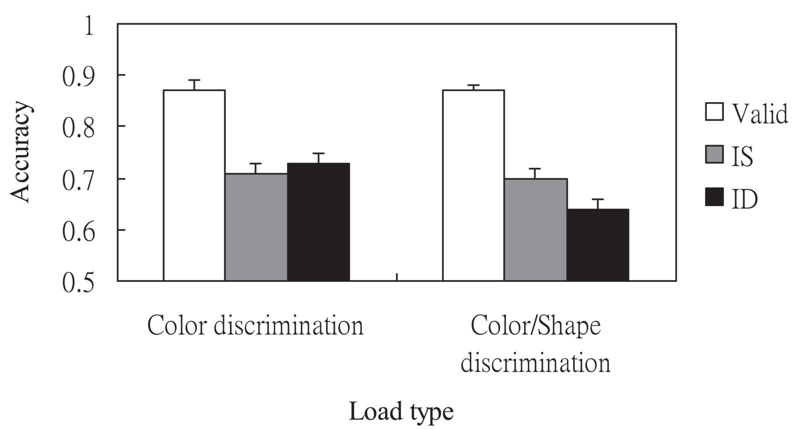
In the practice, buffer, calibration and formal trials, after a variable target presentation time, one mask appeared to replace the target. The fixation and double rectangles remained on the screen. After a 300-ms mask presentation, a brief sentence in Chinese “Press key to respond” appeared at the center of the monitor to indicate the start of responses. This sentence stayed on the screen until a response had been made. Participants were instructed to respond as accurately as possible.

## Results and Discussion

Data from Experiment 2 are presented in Figure 4. In the low-load task, accuracy rates were 82 % and 84 % in the object-absent and object-present conditions, respectively, and the mean target presentation durations were 25 ms (*SD* = 14 ms) and 24 ms (*SD* = 11 ms) in these two conditions. In the high-load task, accuracy rates were 81 % and 83% in the object-absent and object-present conditions, respectively, and the mean target presentation durations were 55 ms (*SD* = 12 ms) and 55 ms (*SD* = 10 ms) in these two conditions.

When the objects were present, a two-way mixed ANOVA of load type (low or high) × cue validity (valid, IS or ID) on ACC was conducted. The main effect of

Object-present condition:




Object-absent condition:

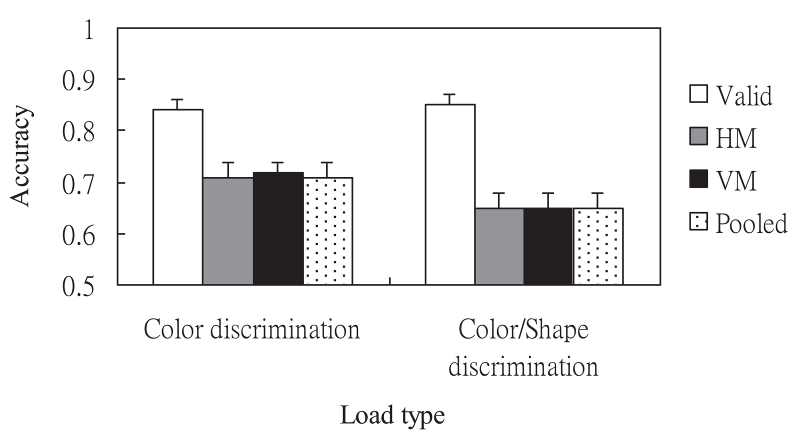



***Figure 4.*** **Mean ACCs across conditions in Experiment 2. Standard errors of mean are shown in the parenthesis. V = valid, IS = invalid-same, ID = invalid-different, HM = horizontal movement, VM = vertical movement, Pooled = pooled HM RT and VM RT.**

cue validity, $F(2, 76) = 61.72$, $MSE = .0067$, $p < .0001$, $\eta_p^2 = .619$, and the interaction effect, $F(2,76) = 4.38$, $MSE = .006$, $p < .05$, $\eta_p^2 = .103$, were significant. Further analysis on main effect of cue validity revealed better performance in the valid condition (mean ACC = .87) than those in the ID (mean ACC = .69) and IS (mean ACC = .71) conditions (all *p*s < .0001). There was no significant difference between the latter two invalid conditions, $F(1,39) = 1.52$, $MSE = .005$, $p = .224$, $\eta_p^2 = .038$. The main effect of load type was not significant, $F(1,38) = 3.58$, $MSE = .011$, $p = .066$, $\eta_p^2 = .086$. This non-significant load type main effect might be because that the current experiments adjusted the target exposure durations to maintain the mean accuracy about 80% in both high- and low-load conditions.

Further analysis on the interaction effect showed that only in the high-load, but not low-load, task was there an accuracy difference between the IS and ID conditions. In the low-load condition, the post hoc paired comparisons showed that performance in the valid condition (mean ACC = .87) was better than performances in the IS (mean ACC = .71) and ID (mean ACC = .74) conditions (all *p*s < .0001). There was no significant difference between the latter two conditions, $F(1,19) = 1.52$, $MSE = .003$, $p = .251$, $\eta_p^2 = .069$. In the high-load condition, performance in the valid condition (mean ACC = .87) was significantly better than those in the IS (mean ACC = .70) and ID (mean ACC = .64) conditions (all *p*s < .0001). More importantly, the performance in the IS condition was better than that in the ID condition, $F(1,19) = 7.71$, $MSE = .005$, $p < .05$, $\eta_p^2 = .289$, revealing attentional selection on the attended object.

When the objects were absent, a two-way mixed ANOVA of load type (low or high) × moving direction (valid, horizontally or vertically) on ACC was conducted. The main effect of load type, $F(1,38) = 2.72$, $MSE = .02$, $p = .107$, $\eta_p^2 = .07$, and interaction, $F(2,76) = 2.20$, $MSE = .008$, $p = .118$, $\eta_p^2 = .06$, were not significant. Again, the adjustment of target exposure durations to maintain 80% accuracy in both high- and low-load conditions might cause this non-significant load type main effect. Only the main effect of cue validity was significant, $F(2,76) = 46.41$, $MSE = .008$, $p < .0001$, $\eta_p^2 = .55$, triggered by better performance in the valid condition (mean ACC = .85) than those in the horizontal movement (mean ACC = .68) and vertical movement (mean ACC = .69) conditions (all *p*s < .0001). There was no significant difference between the latter two invalid conditions, $F(1,39) = 0.04$, $p = .84$, $\eta_p^2 = .001$, ruling out a possibility of meridian effect.

In addition to accuracy rate, a two-way mixed ANOVA of load type × cue validity on correct RT was also conducted. The main effects of cue validity, $F(2, 76) = 16.44$, $MSE = 26502.0$, $p < .0001$, $\eta_p^2 = .302$, and load type, $F(1, 38) = 26.46$, $MSE = 291909.6$, $p < .0001$, $\eta_p^2 = .410$, were significant. The interaction effect was not significant, $F(2, 76) = 0.86$, $MSE = 26502.0$, $p = .426$, $\eta_p^2 = .002$. Further analysis on main effect of cue validity revealed shorter RTs in the valid condition (mean RT = 568 ms) than those in the ID (mean RT = 754 ms) and IS (mean RT = 742 ms) conditions (all *p*s < .0001). RTs in the IS and ID conditions were not significantly different, $F(1, 39) = 0.10$, $MSE = 27666.3$, $p = .752$, $\eta_p^2 = .003$. Finally, main effect of load type revealed longer RTs in the high-load condition (mean RT = 992 ms) than in the low-load condition (mean RT = 504 ms). As in Experiment 1, the author also compared valid RTs between the high- (mean RT = 841 ms) and low-load (mean RT = 294 ms) tasks, and obtained a significant difference, $F(1, 38) = 46.52$, $MSE = 64382.1$, $p < .0001$, $\eta_p^2 = .55$.

Also, when the objects were absent, a two-way mixed ANOVA of load type × moving direction on correct RT was conducted. The main effects of load type, $F(1, 38) = 25.01$, $MSE = 289540.8$, $p < .0001$, $\eta_p^2 = .40$, and moving direction, $F(2, 76) = 17.17$, $MSE = 22812.5$, $p < .0001$, $\eta_p^2 = .31$, were significant. The former effect indicated a shorter RT in the low-load task (mean RT = 423 ms) than in the high-load task (mean RT = 914 ms). The latter effect indicated shorter RTs in the valid condition (mean RT = 556 ms) than those in the horizontal movement (mean RT = 706 ms) and vertical movement (mean RT = 743 ms) conditions (all *p*s < .0001). RTs in the latter two conditions were not significantly different, $F(1, 39) = 1.12$, $MSE = 23836.8$, $p = .297$, $\eta_p^2 = .028$. There was no interaction effect, $F(2, 76) = 0.95$, $MSE = 22812.5$, $p = .391$, $\eta_p^2 = .024$.

Note that the abovementioned RT results in the data-limited ACC-based Experiment 2 should be interpreted with caution. Participants in the current experiment were instructed to respond as accurately as possible without worrying about the response speed. Therefore, ACCs, rather than RTs, was considered a major dependent variable.

It is suggested that data-limited ACC measure is affected by voluntary, rather than involuntary, attention (e.g., Prinzmetal et al., 2005). Since the experimental condition (e.g., adoption of an exogenous cue) in Experiment 2 may involve only involuntary attention, it is suggested that the data-limited ACC measure may not be an appropriate method to test the sensory enhancement account. Although the current study employed an exogenous cue presented peripherally, it did not necessarily mean that there was no voluntary attention involved. Adopting a peripheral cue with different degree of cue predictability, recent studies (Bartolomeo, Decaix, & Siéroff, 2007; López-Ramón, Chica, Bartolomeo, & Lupiáñez, 2011) reported that participants can implicitly learn the relationship between the cue and the target. This means that participants are able to develop the endogenous expectation regarding this peripheral cue and further modify their strategies of processing this cue. These studies clearly show that voluntary attention is involved in the current experimental condition where an exogenous cue is used.

## General Discussion

Results of Experiment 1 showed that it took less time to switch attention within an object than to switch attention between the same regions in space, favoring the within-object benefit hypothesis. Results of Experiment 2 showed that attention was distributed on the attended object, favoring the sensory enhancement account. The current study adds new knowledge to the underlying mechanisms of OBA (between-object cost vs. within-object benefit). OBA did not only operate as a cost produced by shifting between objects as previous studies suggested, but also operate as a benefit caused by shifting within an attended object. Task type associated with the extent to which the high-level object representations are reliant may be critical for the occurrence of these two different mechanisms (discuss later).

It is suggested that the conjunction discrimination task is not necessarily a high-load condition; therefore, the manipulation of conjunction vs. feature discrimination could not be equivalent to the manipulation of perceptual load (e.g., Fournier, Brown, & Winters, 2002). However, the author argues that this viewpoint may not be a mainstream opinion currently, since many relevant studies also manipulated perceptual load via manipulation of conjunction/feature discrimination. Moreover, their study (i.e., Fournier et al., 2002) has not been published yet; which may indicate that their study still requires further test to build up the validity and reliability. A recent study by Tsal and Benoni (2010) suggested that manipulation of number (e.g., one or six) of items in a display (another common way to manipulate perceptual load) may not affect attentional demand, but the extent to which attention is degraded by the items (a dilution effect). Since Tsal and Benoni (2010) did not manipulate the conjunction/feature discrimination, they suggested that their result may not be generalized to studies manipulating perceptual load without display size.

### Between-Object Costs or Within-Object Benefits in the RT-Based Cuing Tasks?

The finding of the within-object benefits in Experiment 1 conflicted the finding of the between-object costs using the cuing task and object-absent baseline (e.g., Brown & Denney, 2007; Ho & Atchley, 2008). It is possible that the between-object costs associated with the disengagement operation from the attended object were actually the within-object benefits where the scanning priority is assigned to the attended object (see also General Discussion in Brown & Denney [2007]). For example, Brown and Denney (2007) reported that shifting from an object to a location was slower than shifting from a location to an object and shifting from a location to another location. This could be accounted for by assuming that within-object locations are always given the highest priority to scan (the attentional prioritization account), thus shifting from an object is slower than shifting from a location. However, the attentional prioritization account fails to account for the result that shifting from a location to an object is slower than shifting from a location to another location, thus Brown and Denney (2007) suggested that disengagement account cannot be accounted for by the attentional prioritization account. Similarly, the attentional prioritization account is unable to account for Ho and Atchley's (2008) results. The attentional prioritization account predicts faster attentional shifting between two locations within the attended object than between the same locations but in the empty space. However, Ho and Atchley (2008) reported comparable attentional shifting within the attended object and the empty space, against the attentional prioritization account.

It is also possible that different visual stimuli complexity between the object-present (more complex) and object-absent (less complex) conditions may account for the within-object benefit. If stimuli complex is important, a grand mean RT difference between the object-present and object-absent conditions should be expected. However, an ANOVA of object presence (present or absent) × load type (high or low) showed only the main effect of load. This indicated that object presence (stimuli complexity) did not affect RT. Additionally, if stimuli complexity is an important variable causing within-object benefit, it would be difficult to explain why previous studies using similar stimuli (e.g., Brown and Denney [2007] and Ho and Atchley [2008]) reported between-object cost.

Finally, it is possible that the within-object benefit obtained in the current study may be due to more reliance on the high-level object representations in the discrimination tasks (Brawn & Snowden, 2000; Vecera & Farah, 1994). For example, participants in Brawn and Snowden (2000; Experiment 7) completed a detection task and a discrimination task in both object-present and object-absent conditions to investigate the extent of reliance on object representations to accomplish these tasks. In the object-present condition, two triangles with different colors (one red and one green) were overlaid to form a Star of David, each of which was made of three connected circles. In the object-absent condition, the lines that joined the circles were removed to form six individual circles (three red and three green circles). Participants were informed before each trial regarding which of the two triangles (object-present condition) or which group of circles (object-absent condition) had a greater chance to contain a target. Brawn and Snowden (2007) reported that in the discrimination task, the cue validity effect was larger in the object-present condition than in the object-absent condition; whereas in the detection task there was no cue validity effect in any of the conditions. They suggested that the discrimination task relies more on object representations; therefore, removing the connecting lines forming the triangles considerably reduces the cue validity effect. Since performance of target discrimination is improved when this target is embedded in an object, rather than in spatial regions without objects (Brawn & Snowden, 2000), it is possible that discriminating a target within an attended object, rather than an unattended object, might be facilitated (a within-object benefit; see also Shomstein & Behrmann, 2008).

Event-related potentials (ERPs) studies have shown that the N1 component (140 ~ 180 ms post-stimulus) increased in responding to the target onset (a detection task; e.g., He, Fan, Zhou, & Chen, 2004) or target-related feature (a discrimination task; e.g., Martínez et al., 2006) when it appeared at an unattended location of an attended object, compared to when it appeared at an unattended location of an unattended object. Because spatial attention also modulates the amplitudes of P1 and N1 components (for a review, see Hopfinger, Luck, & Hillyard, 2004), this suggests that object representation may be a grouped array of locations conforming to the object's shape (Vecera, 1994; Vecera & Farah, 1994). In addition to this grouped-array representation in the early phase of process, recently Kasai (2008) suggested that attention could be guided by the unity of an object in a later phase of the process. In his ERP study, participants attended to either left or right visual field in response to a target embedded in the bilateral stimuli, either unconnected or connected. When connected, the bilateral stimuli could be connected weakly by a thin line or strongly by a thick line. Kasai (2008) reported the largest amplitude of N1 component (150 ~ 210 ms post-stimulus) at the hemisphere sites contralateral, rather than ipsilateral, to the attended hemifield when the bilateral stimuli were strongly connected, intermediate when weakly connected, and little when unconnected. This indicated that in an early process, attention was directed to the visual field opposite to the attended field as the extent of perceptual grouping increases. Moreover, he reported that the enlarged amplitude of N2pc (posterior-contralateral) component (330 ~ 390 ms post-stimulus) at the hemisphere sites contralateral, rather than ipsilateral, to the attended hemifield when the bilateral stimuli were connected both weakly and strongly. This reflected that in a later process, attention was guided to the unity of connected objects. Kasai (2008) suggested that attention could be guided twice in association with an early grouped-array representation and a later unity of connected objects. Task type is considered critical in determining which level of representation attention operates (Brawn & Snowden, 2000; Kasai, 2008; Vecera & Farah, 1994). In the discrimination task, attention relies more on the use of later representation, such as object unity, whereas in the detection task, attention relies more on the use of earlier representation, such as grouped array. Therefore, in the current study, target discrimination could be facilitated by attentional tracing along the contour of the attended rectangle (good object unity; Avrahami, 1999), producing a within-object benefit.

## Sensory Enhancement Account or Attentional Prioritization Account?

The results from Experiment 2 suggested that within-object benefits were caused by improved representation of the attended object (the sensory enhancement account), rather than attentional scanning priority assigned to the attended object (the attentional prioritization account). The current results in Experiment 2 were different from Ho and Atchley (2009) in that in our case, accuracy difference between IS and ID was found only in high-load condition, but Ho and Atchley (2009) reported accuracy difference in both low- and high-load conditions. Specifically, Ho and Atchley (2009) manipulated the cue-target distance and found attentional selection over the cued object to different extents in low- (color feature) and high-load (color/shape conjunction) conditions. That is, when identifying a color feature, the near and far locations on the cued object can be selected; whereas when identifying a color/shape conjunction, only a near location on the cued object can be selected. We suggest that this inconsistency may be caused by the interplay between target spatial uncertainty and perceptual load level.

Target spatial uncertainty was a function of the numbers of possible target locations and the numbers of cue-target distances. In Ho and Atchley (2008), the invalidly-cued target could appear on one of four possible locations and it could appear on the locations either near to or far from the cued location. On the other hand, the current study had relatively fewer invalidly-cued target locations (only two) and the cue-target distance was always fixed. The spatial uncertainty in the Ho and Atchley's case was supposedly larger than the current study. Attentional allocations on the objects may be flexible and differ across the conditions in which the spatial uncertainty is larger (e.g., Ho & Atchley, 2009), smaller (e.g., the current study) or absent (i.e., 100% certainty; e.g., Chen & Cave, 2008; Richard et al., 2008). In the condition of large spatial uncertainty, attention may be allocated more on the cued object in which the cue and the target on this object were grouped through the common region principle (Palmer, 1992). In such a condition, perceptual load level can modulate the extent to which an attended object can be selected. On the other hand, when the spatial uncertainty is relatively smaller (e.g., the current study), attention may be relatively less reliant on the cued object (Drummond & Shomstein, 2010). In addition, a low-load condition (e.g., identifying a color feature) may even make attentional selection to a larger spatial proximity (Caparos & Linnel, 2009; Lavie, 1995; Müller et al., 2005). Therefore, it may be less likely that attentional selection between objects would be different in the condition where both spatial uncertainty and perceptual load are low. When perceptual load increases (e.g., identifying a color/shape conjunction), attention is more likely to be distributed on the attended object. Systematic manipulation of spatial uncertainty and perceptual load level is required to examine how these two factors influence attentional selection over object.

Recent flanker studies (e.g., Chen & Cave, 2008; Ho, 2011; Richard et al., 2008) presented the target with 100% certainty on the intersection of the two crossed rectangles and reported attentional selection on the attended rectangle. At first glance, this seems to conflict the spatial uncertainty hypothesis in that 100% certainty should lead to attentional distribution only on the target location, but not to the attended object. Notably, these flanker studies usually used very short target-flanker distance (less than 1°), in comparison to the cuing studies. Thus, when the target location is highly focused, attention may still select the regions on the attended object (e.g., Ho, 2011). But this same-object attentional selection is strongly constrained by the spatial distance, perhaps within only 1° distant from the target location. The flankers very close to the target were therefore sensitive enough to detect this spatially-constrained attentional selection.

## Appropriateness of the Object-Absent Baseline

The object-absent baseline was used to measure attentional movement from one location to another location when there were no boundaries present. The use of this baseline may rest on the assumption that nothing else of importance changes when the boundaries are present or removed. For example, attention may be allocated differently across quadrants or hemifields in an empty display (a meridian effect; e.g., Hughes & Zimba, 1985, 1987). However, when the possible target locations are marked with the small squares, attention could be allocated in a gradient mode centered from the cued location (e.g., Downing & Pinker, 1985). This possible allocation difference between object-absent display and object-present display may make the object-absent baseline inappropriate.

However, the above concern may be minor because a meridian effect may be less likely to occur in the current study. Many have shown that a meridian effect is usually obtained when attention is oriented endogenously (for a brief review, please refer to Dori & Henik, 2006), but not exogenously (e.g., Egly & Homa, 1991; Henderson & Macquistan, 1993). Therefore, the exogenous cue employed in the present study was less likely to induce a meridian effect in the object-absent baseline. Moreover, the performances in the two invalid-cue conditions in the object-absent baseline recorded by either the RT measure (Experiment 1) or ACC measure (Experiment 2) were comparable. Therefore, this data supported a gradient mode in the object-absent baseline.

In addition to the empirical evidence from the literature and current data, the author suggests that even if the attentional allocation differs across the displays, it does not necessarily mean the adoption of current baseline is inappropriate. The current study asked whether the object effects obtained in the presence of objects were a result of object-related cost or benefit. Because this research question regards the effects when the objects are present, one way to answer this question directly is to have an object-absent condition to compare with. To account for the comparison results, the possible differences (e.g., the possible allocation difference) between these two conditions should also be considered.

# Note

1. It is also possible that the between-object cost and within-object benefit are not mutually exclusive to each other. However, a review of the current literature does not appear to support the co-occurrence of cost and benefit. It is interesting to investigate this possibility in the future.
2. We realized that because of the constraints of hardware (e.g., refresh rate), it was impossible to produce a precise 2-ms duration. To obtain a precise estimation of target duration, we computed the time difference between target onset time and mask onset time, because it has been suggested that for most display events, the actual duration must be computed as the difference between the stimulus onset and the onset of the stimulus that removed or replaced the initial stimulus (Schneider et al., 2002). The accuracy rates in the current data-limited experiment reached the expected goal, indicating that the adjustment procedure was effective.

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# 物體為基注意力：辨認作業中的物體內優勢與感覺增強

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過去研究發現，偵測位在相同物體上的目標，比偵測相同距離但位在不同物體的目標，來得快速，顯示了物體效應。本研究探討辨認作業中所觀察到的物體效應是否是物體內優勢或者物體間代價。實驗一採用Egly、Driver及Rafal（1994）的線索典範，並加入無物體基準線，來探討此問題。知覺負荷亦被操弄，亦即低負荷的顏色辨認作業，以及高負荷的顏色／形狀結合辨認作業。實驗結果支持物體內優勢。本研究進一步探討，是否此物體內優勢是感覺增強，還是注意優先所產生。實驗二採用資料有限正確率之方法來測量表徵的品質。結果顯示在低負荷時，注意力以類似的方式分布在有注意到與沒注意到的物體。但在高負荷時，注意力主要分布在注意到的物體，支持感覺增強。本研究之重要意涵也在文中討論。

關鍵詞：注意優先、基準線、優勢、代價、感覺增強